Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	}	
	}	
Revision of Part 15 of the Commission's	}	
Rules Regarding Ultra-Wideband	}	ET Docket No. 98-153
Transmission Systems	}	

Reply Comments of Multispectral Solutions, Inc.

Multispectral Solutions, Inc. (MSSI) is pleased to submit these reply comments in response to the Notice of Proposed Rule Making (NPRM), FCC 00-163, in the above referenced proceeding. More specifically, these reply comments address the most recent reports[1] from the NTIA on the potential for ultra wideband (UWB) transmission systems to cause harmful interference to U.S. Government radio operations between 400 MHz and 6000 MHz.

First of all, MSSI highly commends the NTIA on the excellent and thorough test and analysis it performed of the interference potential of UWB devices to federal systems. In our assessment of these documents, the reported results correctly and accurately reflect the true nature of UWB emissions and their effects. We are also pleased that we were able to provide the NTIA with relevant UWB hardware for use in conducting these tests.

In its 27 October 2000 Reply Comments to ET Docket 98-153, MSSI provided the following four recommendations:

1. Permit the initial use of unlicensed UWB devices in the frequency range *above* 3.1 GHz (with special consideration to the unrestricted band from 5.46 to 7.25 GHz);

2. Permit UWB operation in bands above 3.1 GHz at power levels commensurate with existing Part 15 devices (i.e., 1 Watt peak with +6 dBi antenna gains), but relax the peak-to-average ratios from the current 20 dB limitation to the proposed 60 dB limit to properly reflect the low duty cycle advantage of a well designed UWB emitter;

3. Continue with UWB testing and an extended comment period for consideration of UWB operation *below* 3.1 GHz; and continue to monitor the waivers granted to Time Domain, U.S. Radar and Zircon as they shed light upon the effects of UWB systems in this frequency range; and,

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[1] "The Temporal and Spectral Characteristics of Ultrawideband Signals," William A. Kissick, editor, NTIA Report 01-383, January 2001 (http://www.its.bldrdoc.gov/pub/ntia-rpt/01-383/).

"Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems," Brunson, L.K. et al., NTIA Special Publication 01-43, January 2001 (http://www.ntia.doc.gov/osmhome/reports/uwb/uwb.pdf).

4. Alternatively, consider licensing for applications requiring frequencies below 3.1 GHz.

In light of these two recent NTIA reports, these recommendations appear all the more appropriate. Specifically, with respect to MSSI's first two recommendations:

1. *Permit the initial use of unlicensed UWB devices in the frequency range above 3.1 GHz (with special consideration to the unrestricted band from 5.46 to 7.25 GHz);*

   NTIA measured the temporal and spectral characteristics of 5 UWB devices; assessed commercial-off-the-shelf (COTS) approaches for the measurement of UWB devices; measured the effects of UWB signals on 3 Federal Government systems in the field; and performed limited measurements of UWB aggregate effects. Analytical techniques were used to evaluate the effects of UWB devices on an additional 12 Federal Government systems.

   The NTIA demonstrated the potential of certain classes of UWB equipment, particularly those with high pulse repetition frequencies (PRFs), to significantly degrade the performance of a wide assortment of Federal Government systems operating below 3.1 GHz, even if the UWB systems radiated within existing FCC Part 15 limits.

   The conclusions reached by the NTIA in this first round of testing were succinctly summarized as follows:

   (a) "[O]peration of UWB devices is feasible in portions of the spectrum between about 3.1 and 5.650 GHz at heights of about 2 meters with some operating constraints." It was pointed out that additional constraints are needed at greater UWB heights and near low elevation angle 4 GHz FSS Earth Stations; and,

   (b) "Operations of UWB devices below 3.1 GHz will be quite challenging and any policy developed will need to consider the results of analyses of interactions of GPS and UWB systems underway at NTIA and other facilities." The report also stated that "widespread, dense uses will be hard to accommodate".

   The NTIA limited its evaluation to the frequency range from 400 MHz to approximately 6.0 GHz. The potential impact of higher frequency UWB systems was not considered in the NTIA analyses.

   Thus,

   The restriction of UWB operation to frequencies only above 3.1 GHz is supported by NTIA test data. The NTIA demonstrated the potential for *significant* interference to existing federal Government systems from UWB emissions operating anywhere below that frequency cutoff.

   The NTIA data suggests that the FCC consider a significant reduction (e.g., better than -40 dB from peak levels) in UWB emission levels below 3.1 GHz. In

particular, a -12 dB level of protection as suggested in the NPRM is totally inadequate to protect existing Government systems.

2. *Permit UWB operation in bands above 3.1 GHz at power levels commensurate with existing Part 15 devices (i.e., 1 Watt peak with +6 dBi antenna gains), but relax the peak-to-average ratios from the current 20 dB limitation to the proposed 60 dB limit to properly reflect the low duty cycle advantage of a well designed UWB emitter;*

   The NTIA demonstrated that high pulse repetition frequency (PRF) UWB emitters (*with or without* incidental pulse train dithering[2]) had the highest potential for interference to existing services below 3.1 GHz.

   For a given operational bandwidth B; the higher the PRF, the higher the pulse duty cycle δ and the lower the peak-to-average ratio $R_{pk\text{-}ave}$. These parameters are simply related by the following expression:

$$d = \frac{PRF}{B} = \frac{1}{R_{pk-ave}}.$$

   The NTIA also demonstrated that, at UWB PRFs *greater than* the operational or resolution bandwidth (RBW) of the victim receiver, the power P received by the victim receiver (relative to the total transmitted power P_T) was proportional to the square of the ratio of the PRF to the total radiated bandwidth (successive UWB pulses are integrated by receiver filter)

$$P \approx \left(\frac{PRF}{B}\right)^2 P_T \quad \text{for } PRF > RBW\,;$$

   and that, for UWB PRFs *less than* the operational or resolution bandwidth (RBW) of the victim receiver, the power P received by the victim receiver was proportional to the square of the ratio of RBW to the total radiated bandwidth (UWB pulses remain separate and distinct within receiver)

$$P \approx \left(\frac{RBW}{B}\right)^2 P_T \quad \text{for } PRF < RBW\,.$$

   These results have extremely important ramifications for future commercial use of UWB technology:

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[2] Contrary to the claims made by several UWB proponents that pulse dithering significantly reduces the potential for interference to other systems, the NTIA has demonstrated that the effects of dithering (even at very large percentages) are negligible (less than a few dB improvement) to nonexistent. This fact was also pointed out to the FCC by MSSI in its 12 September 2000 response to the NPRM.

> As an example, a 1 Watt peak UWB signal having a pulse repetition frequency of 1 Mpps (one million pulses per second) and an instantaneous bandwidth of 1 GHz, produces a peak field strength intensity of 1,826 μV/m and an average field strength intensity of 1.83 μV/m at 3 meters as measured in a 1 MHz bandwidth. (The peak-to-average ratio is $[10^6 \times 10^{-9}]^{-1}$ = 1000 or 60 dB – note: 20 log dB ratios are used to express peak-to-average ratio.) Note that the average field strength of 1.83 μV/m is *48 dB below* the existing Part 15 limit![3]
>
> If the same waveform is now operated at a 100 Mpps rate, the measured peak field strength intensity (again in a 1 MHz resolution bandwidth) becomes 182,600 μV/m with an average field strength intensity of 18,260 μV/m, *31 dB above* existing Part 15 limits or 80 dB worse than the first example! (The peak-to-average ratio for this example is only 10 or 20 dB.)

Thus, high PRF UWB systems – particularly those operating at rates greater than about 1 million pulses per second[4] – can create extremely high peak and average field strength intensities; and, as shown by both the NTIA and DOT testing at Stanford University, can create havoc with existing narrowband and wideband systems operating in the same frequency band.

On the other hand, low to moderate PRF UWB systems – even operating at peak levels commensurate to those presently allocated to spread spectrum systems – have been shown to have negligible effect on other systems.

These are critical results that are apparently not well understood by many UWB proponents. The advantage that UWB has had in covert military systems has been due to the fact that such systems operate with extremely low pulse duty cycles; and, hence, with miniscule average field strength emissions as shown above. However, most UWB proponents have assumed that LPI/D (and, hence, low probability of interference to other services) is a natural consequence of utilizing short pulse or impulse systems, irrespective of the pulse rate used. Unfortunately, as shown above and by Stanford and the NTIA, the claims that UWB systems operating at 10's of megabits per second and higher do not cause interference are totally baseless. High data rate UWB systems *will* interfere with existing services if operated over the same frequency bands.

MSSI has recommended that the FCC adopt a peak power constraint for UWB emissions. However, as demonstrated above, a peak power constraint will only minimize the potential for interference if high PRFs are prohibited.

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[3] Existing Part 15 rules limit the maximum peak-to-average ratio for regulatory purposes to 20 dB, thereby effectively penalizing low duty cycle, short pulse waveforms. In this example, the average field strength intensity would be considered as 182.6 μV/m, although still within Part 15 limits of 500 μV/m.

[4] Note that it is the actual number of pulses per second (pps) transmitted that determines the measured field strength intensity, and not the effective data rate. One UWB proponent has claimed 40 Mb/s, yet a published technical paper indicated a pulse rate of 40 Mpps and a data rate of only 156 kb/s due to the use of 256 pulses per bit of information transmitted.

Thus,

NTIA (and DOT/Stanford) test data demonstrates that high PRF UWB systems, with or without pulse-to-pulse dithering, are the most destructive in terms of potential interference to existing services. Data strongly suggests that the FCC limit the maximum PRF available for UWB operation to prevent such interference potential.

MSSI has recommended that the FCC consider a peak power constraint for UWB emissions comparable to those imposed upon direct sequence and frequency hopped spread spectrum transmissions. However, such peak power constraints must be tempered by a corresponding restriction on the maximum PRF (hence, maximum pulse duty cycle) to prevent high peak and average field strength emissions. Given existing measurement techniques, and the current state-of-the-art in receiver technology, a maximum PRF of 1 to 10 million pulses per second (1 - 10 Mpps) appears warranted.

Respectfully submitted,

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